Key Issues for the 2020+ Integrated CNS Architecture

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Agenda/Objectives

- Summarize the key issues developed in a recent CNS technology "gap" analysis.
- Report on Narrowband Communications Loading.
- Foster awareness of future benefits from the use IP-based protocols.
- Stimulate discussion for guidance in direction of future research activities.

"Gap" Analysis Approach

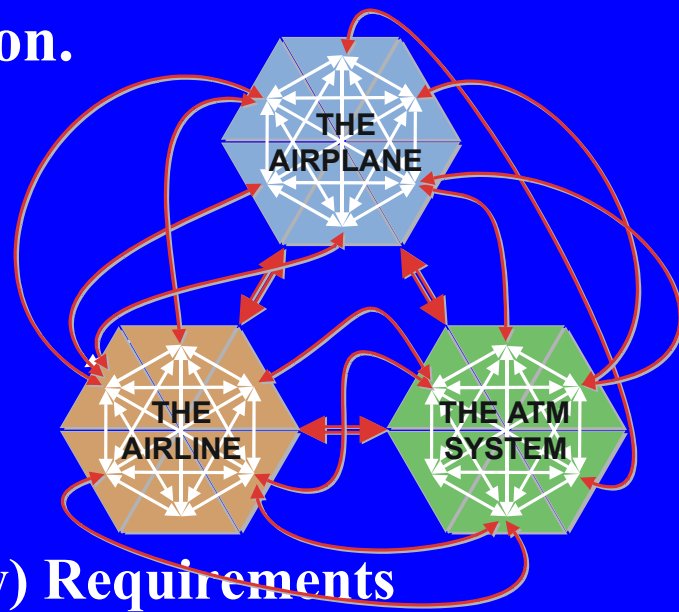
- **Conduct a CNS Technology Needs "Gap" Assessment between the forecast outcomes of the current aviation industry projects and envisioned Free Flight Concepts**
- **Track 1. Far Term**
  - **Build upon TO-24 SAIC Communications Architecture Study and add the 2020 (plus) Vision.**
  - **Objects/Functions/Data Exchanges**
  - **Traffic Loading/Models**
- **Track 2. Near Term**
  - **Subnetwork Technology**
  - **Related to Capacity and Safety**
- **Program Evaluations**

Vision 2020+

- Each Constituent has Multiple Internal and External Direct Connections with the Others, and the World - creating the air commerce web.

Macro-level Architecture Analysis

- Capture the interaction and the collaboration that is critical to achieving the system efficiency required to support the 2020 Air Commerce Vision.
- Keep trace to applications context.
- Open minded approach.
- Treat Groupings versus discrete.
- Four steps to define the need:
  - 3a. Entity/Functional Architecture
  - 3b. Information Exchange (data flow) Requirements
  - 3c. Communication Performance Requirements
  - 3d. Traffic Loading and Models



Macro-Level Object Oriented Analysis Process

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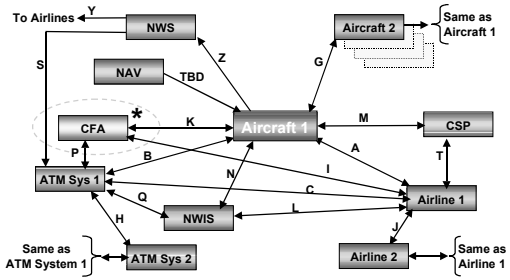
Operational Services/Vision

REF	USER SERVICES
1	*Flight Plan Service*
2	*ATC Separation Service*
3	*ATC Advisory Service*
4	*Traffic Management – Synchronization Service*
5	*Traffic Management – Strategic Flow Service*
6	*Emergency and Alerting Service*
7	*Navigation Service*
8	*Airspace Management Service*
9	*Infrastructure / Information Management Service*
10	*Aircraft / Airline Operational Service*
11	*Passenger Onboard Services*

Entity and services relationships Reference Model



CFA could be government, government controlled, Independent, private, joint venture, or a public entity.

Services allocated to system entities

Purpose	Function	ATM 1	ATM 2	Airline 1	Airline 2`	Aircraft 1	Aircraft 2	CFA	NWS	NWIS	CSP
• Provide a lost comm separation plan. • Provide SAR information	• File flight plans and amendments	X	X	X	X	X	X				
	• Process flight plans and amendments and approve	X	X								
• **Provide intent information for better air traffic management**	• Provide information for flight plans	X	X	X	X			X	X	X	
• **Contract for airspace use**	• **Dynamically Allocate Airspace elements for contract**	X	X	X	X	X	X	X			

Information Exchange Data Objects allocated by service/ functional processes (data flows)

Purpose	Function	1 ASI	2 WX	3 AS	4 TMC	5 ACPU	6 SMC	7 ACC	8 OS	9 PIE	10 DS	11 NAV
• Provide a lost comm separation plan. • Provide SAR information	• File flight plans and amendments	X				X		X				
	• Process flight plans and amendments and approvals	X	X			X		X				
• **Provide intent information for better air traffic management**	• Provide information for flight plans	X	X			X		X				
• **Contract for airspace use**	• **Dynamically Allocate Airspace elements for contract**					X		X				

Information Exchange Needs (communications requirements)

Information Exchange - Cat 1ASI	Type: A/G,G/G Integrity: 10^{-7} Information Unit Size: Medium (5 Kb) Frequency: 5 /fl Timeliness: 15 second Authentication: No Data Security: No Certification Level: E Reliable Transport: High
Applicable Interface(s): N, L	

+ Loading

Performance Parameters

Gap Issues and Strategic Focus Allocation

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Systems Architecture
•Operation Systems Knowledge
•Functional Analysis
•System Engineering

Gap Issues

- (2) Commoditized Airspace
- (3) Frequency Use and Planning
- (4) Dynamic RF Assignment & Use New Process
- (6) CPDLC-1A System Latency in Terminal Domain
- (10)Transition Planning Central Focus
- (13) Security / Vulnerability
- (14) Network Management
- (16) Airborne Internet

Gap Issues and Strategic Focus Allocation

Systems Modeling
•GACTSEF
•Trials and Demonstrations

Gap Issues

- (1) National Communications Traffic Loading Model
- (11) Performance Test Measurement

Design Engineering
•RF Design
•Communication System Engineering
•Communication Protocols Design

Gap Issues

- (5) VHF RF Improved Data Link Concept
- (7) Impact of CPDLC-1A System Latency
- (8) Multiple Radio Equipage
- (9) Co-site & Antenna isolation
- (12) Satellite Based Communication
- (15) Use of COTS TCP/IP
- (17) Low Cost Systems for GA
- (18) Use of COTS Wireless Onboard (802.11 and Bluetooth)
- (19) VDL M3 Performance Failures Modes
- (20) Human Factors Related Use of Communications Data Links

Highlighted Issue

Traffic Loading Implications for VHF Data Link

Typical IFR A/G Flight Communications

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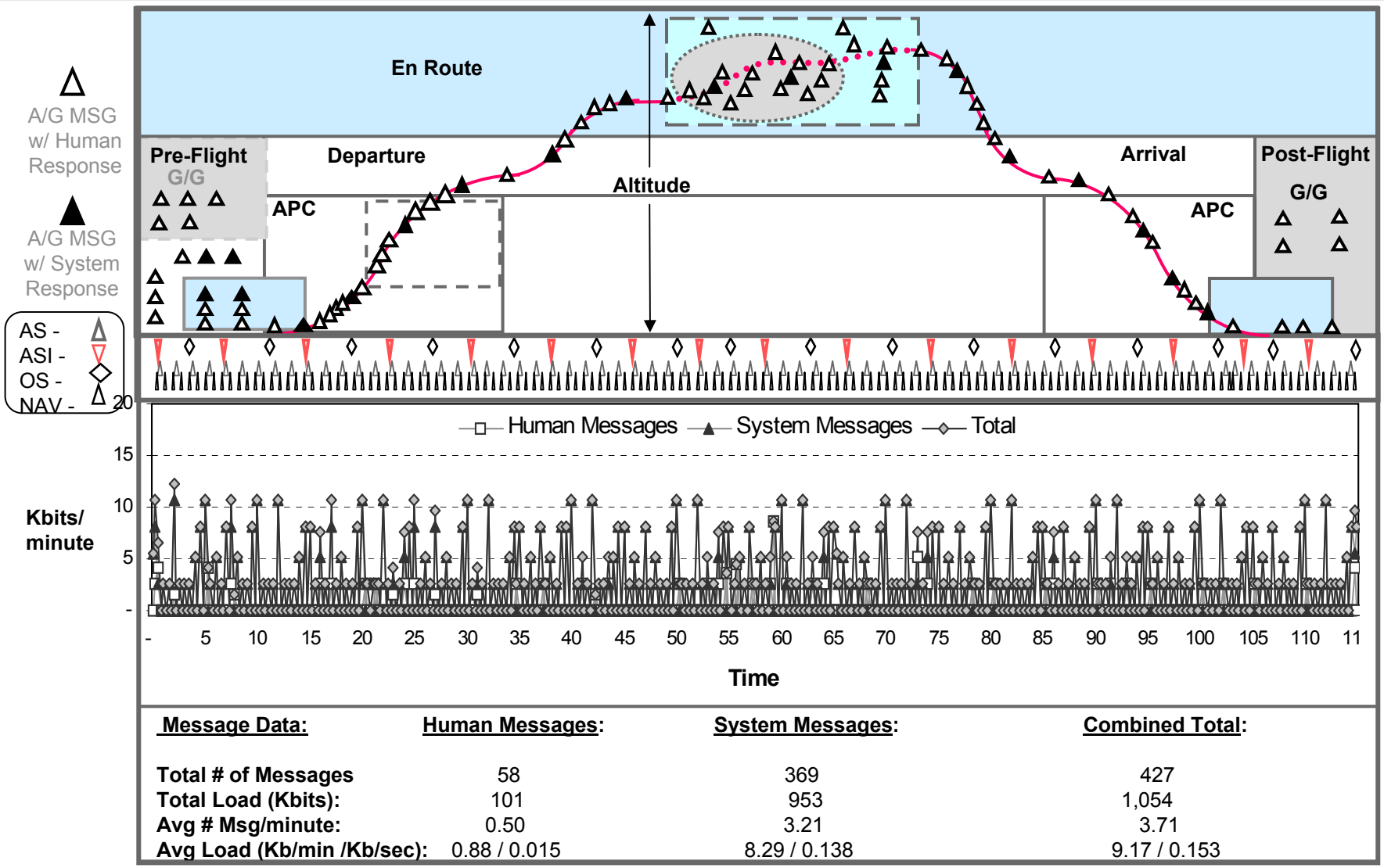

Message Data:	Human Messages:	System Messages:	Combined Total:
Total # of Messages	58	369	427
Total Load (Kbits):	101	953	1,054
Avg # Msg/minute:	0.50	3.21	3.71
Avg Load (Kb/min /Kb/sec):	0.88 / 0.015	8.29 / 0.138	9.17 / 0.153

Airspace and Air Traffic Model - L.A Basin (2020)

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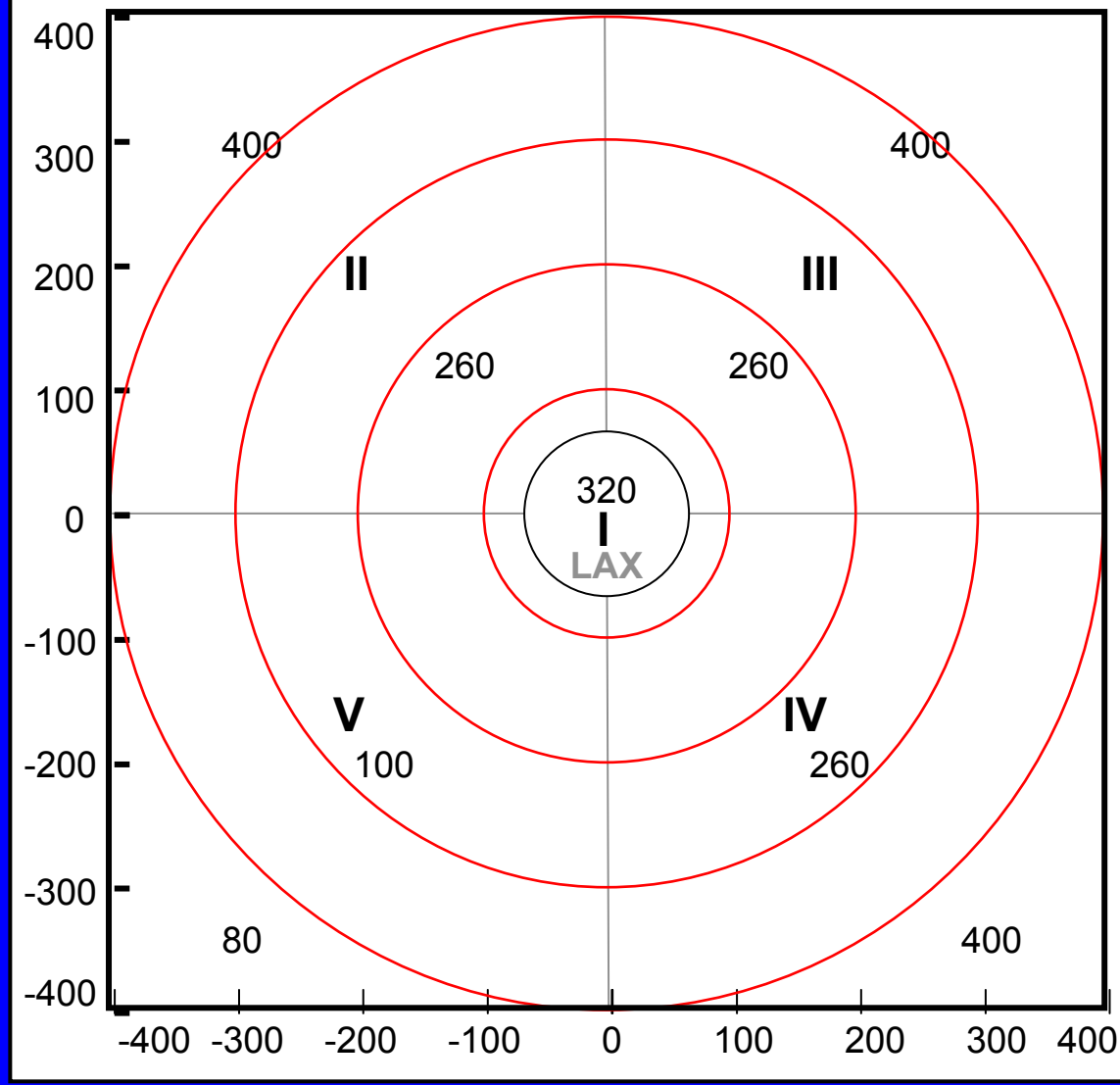

AIRCRAFT OPERATIONS VALUES:

1. Sectorization addresses L.A. Basin airspace for this analysis.
2. Each Sector is assigned an operations value for each airspace strata.
3. Sector A includes the greater L.A. area which includes six IFR airports, and has a greater percentage of lower altitude operations.
4. Sectors B, C, and D are typical, domestic-only airspace.
5. Sector E is primarily offshore and oceanic air traffic, and has its own operations values.

ASSIGNED (%-based) VALUES:

Sector	Airspace Class			
	A	B/C	D	E
I	40	30	10	20
II,III,IV	50	25	5	20
V	70	5	5	20

Constructed Three Media Models

- **De-rated LA Model to forecast Number of Data Link equipped participants and Assigned aircraft to phase of flight and airspace:**

I. Traditional Narrowband Approach

- **Operations Messages (TMC, SMC, ACC, etc.) via VDL2 or 3**
- **ADS/NAV - separate channel**
- **PIE has its own channel**

II. Traditional SATCOM Approach

- **Same as Traditional VHF but uses SATCOM for operational messages**
- **ADS/NAV - separate channel**
- **PIE has its own channel**

III. Expanded High Bandwidth SATCOM Approach

- **All operational traffic**
- **Includes PIE on single channel**

Airspace and Air Traffic Model - L.A Basin (2020)

RF Characteristics Addressed in the Study

- Single-channel issues
  - Media access schemes
  - Generic CSMA capacity and delay curves
  - Impact of message length and reservations
  - Latency requirement
- Multi-channel issues
  - Spectrum for “generic” VHF signal
  - Cosite frequency planning constraints
- Aircraft equipage issues

Airspace and Air Traffic Model - L.A Basin (2020)

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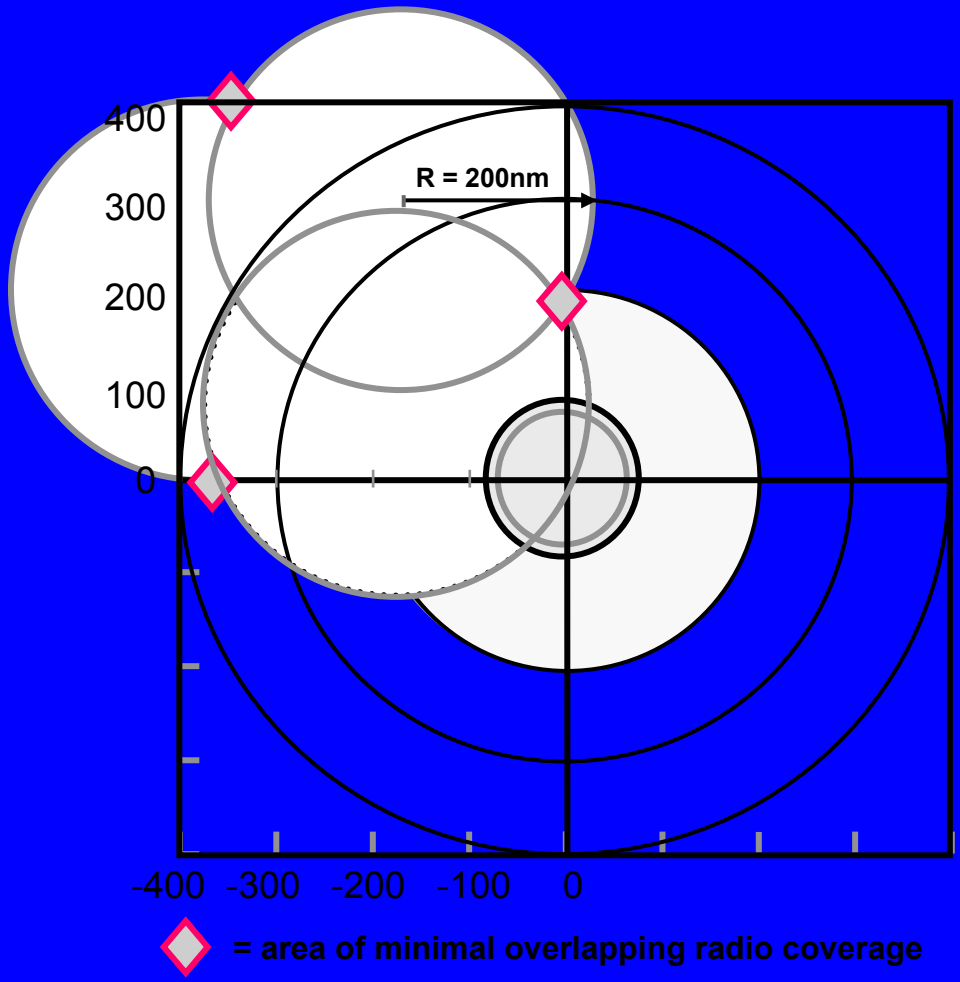
VHF Transmitter/Receiver Site Coverage @ FL200



- Light circles depict nominal sector VHF radio coverage
- Most sectors this size will require more VHF transmitter/receiver sites
- Dark circle depicts LAX sector coverage requirement
- Very light circle depicts the nominal range of the VHF radios used by LAX facilities
- Does not depict the VHF radio coverage required at the six airports within the LAX sector airspace

Airspace and Air Traffic Model - L.A Basin (2020)

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Sector I - L.A. Metropolitan Airspace - 209 Equipped Aircraft

Traditional Media Assignment Model
Narrowband Approach

MEDIA #	Message Types	Phase of Flight (Total # of MSG X Avg Message Size = Total Kb			Average	TOTAL Kb
		Departure	En Route	Arrival		
1 VDL (Mode 2 0r 3) 2	ATM/AOC Ops SMC TMC ACPU SMC ACC DS	966 X 1.26 = **1,217**	2,875 X 2.13 = **6,123**	504 X 1.92 = **968**	1.91	**8,308**
	FIS-B ASI WX OS AS	1,974 X 3.36 = **6,633**	7,125 X 3.68 = **26,220**	1,428 X 3.68 = **5,255**	3.62	**38,108**
3	NAV	2,982 X 1.97 = **5,875**	12,500 X 2.00 = **25,000**	2,520 X 2.00 = **5040**	2.00	**35,915**
Total Kb ÷ # A/C = Kbpm		13,725 ÷ 42 = **326.78**	57,343 ÷ 125 = **458.75**	11,263 ÷ 42 = **268.16**		**82,331**
4	PIE	*35MB*	*30MB*	*30MB*	*N / A*	*115MB*

Does Not include ATN Overhead

Formula: Total Comm Traffic Load = Total kbm ÷ Flight Time = Total Kbpm/60 = Total Kbps

Total Comm Traffic Load 1053.69 ÷ 115 = 9.1625 Kbpm/60 = .153 Kbps

Airspace and Air Traffic Model - L.A Basin (2020)

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Traditional Narrowband Approach (Media Channel 1)
L.A Basin Sector I (209Aircraft)

VDL 2			VDL 3		
Data Channel Capacity in kbps	Traffic load Per Aircraft in kbps	Number of Frequencies Required*	Data Channel Configuration	Traffic load Per Aircraft in kbps	Number of Frequencies Required*
5	0.153	28	2V2D	0.153	24
6		24	3V1D		44
7		20			
8		16	3T		12

* A three (3) channel guard band and no frequency reuse assumed

Airspace and Air Traffic Model - L.A Basin (2020)

L.A Basin Sector II,III and IV (427 aircraft per sector)
Per Sector Requirement

VDL 2			VDL 3		
Data Channel Capacity in kbps	Traffic load Per Aircraft in kbps	Number of Frequencies Required per sector*	Data Channel Configuration	Traffic load Per Aircraft in kbps	Number of Frequencies Required with Separation *
5	0.153	52	2V2D	0.153	44
6		44	3V1D		88
7		40	3T		24
8		36			

* A three (3) channel guard band and no frequency reuse assumed

Airspace and Air Traffic Model - L.A Basin (2020)

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Sector V - Coastal & Oceanic Transition Airspace

L.A Basin Sector V (119 aircraft)

VDL 2			VDL 3		
Data Channel Capacity in kbps	Traffic load Per Aircraft in kbps	Number of Frequencies Required *	Data Channel Configuration	Traffic load Per Aircraft in kbps	Number of Frequencies Required *
5	0.153	16	2V2D	0.153	12
6		12	3V1D		24
7		12	3T		8
8		12			

* A three (3) channel guard band and no frequency reuse assumed

Communications Traffic Model Notes

- No "Accepted" Standard Airspace Model.
- All VDLs will require multiple channels.
- Loading assessment indicates need for large number of channels (M2:146-200) within the LA Basin. Final number could be substantially higher considering:
  - Voice requirements
  - Need for airspace sectorization
  - Coverage below 20,000 feet
  - Terminal requirements/latency
  - Peak or disruptive event loads

Communications Traffic Model Notes

- Message delay requirements are not well understood for adequate tactical use, especially in the approach control and terminal environments. This needs additional study.
- SATCOM may offload some demand from VHF
- Indicates now is the time to start to define the “next, nexcom”

Highligthed Issue

Harmonizing ATN and TCP/IP

Challenge for the Aeronautical World

Can the TCP/IP protocol meet aeronautical requirements?

- Benefits:
  - Lower Infrastructure Cost
  - Potential for New Services, such as:
    - VoIP
    - Multicast
    - Security
    - Integration with Public Infrastructure

Challenges:

- Modifying Political Agreements/Industry Standards
- Addressing Technical Issues for:
  - Mobility Management
  - Policy Based Routing Capability

Today's Briefing is the Results of a Series of Studies

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Aeronautical Applications over TCP/IP and ATN

Potential Aviation Enhancements Achievable Through the Use of TCP/IP

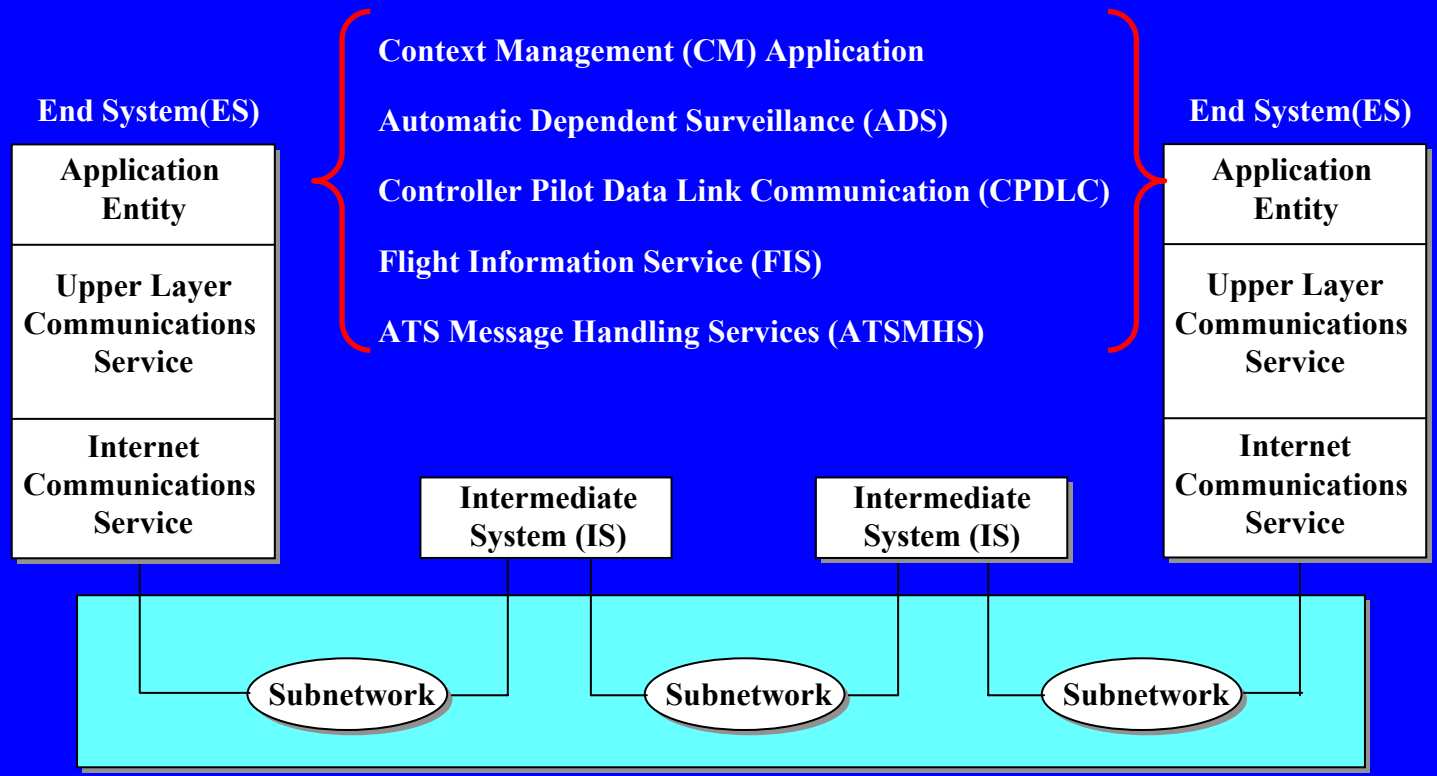
ATN Transport and Network Layers Implementation Cost Analysis

TCP/IP Architecture for Aviation

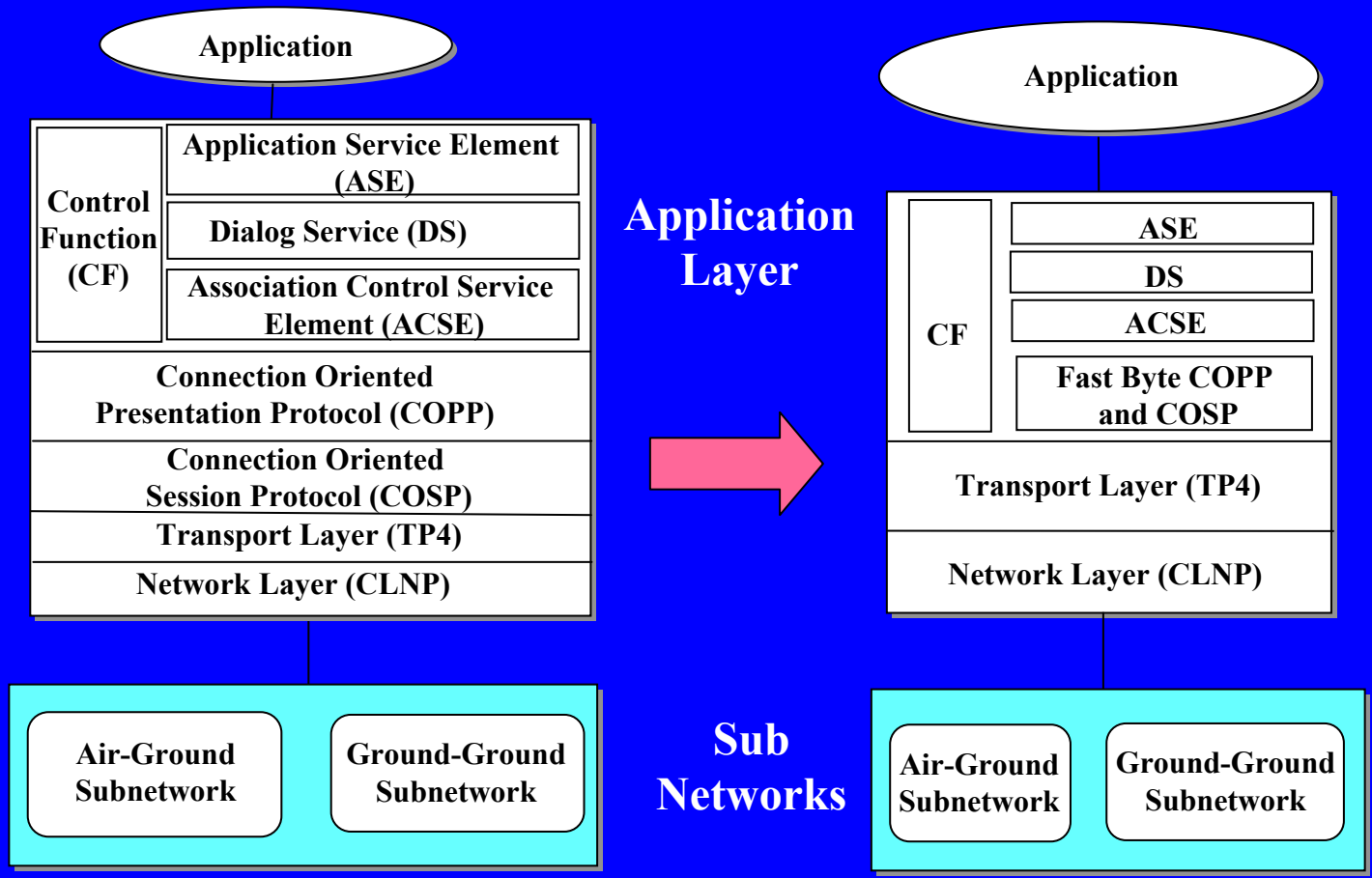
Studies performed under funding from the NASA Glenn Research Center

ATN Architecture

Consists of applications and communication services that allow ground, air-ground, and avionics sub-networks to inter-operate



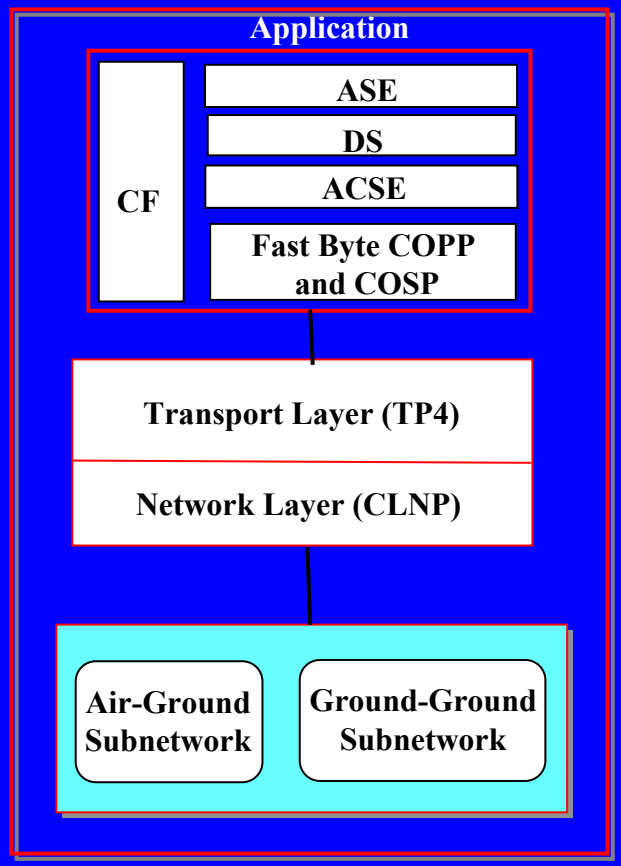
ATN Protocol Architecture



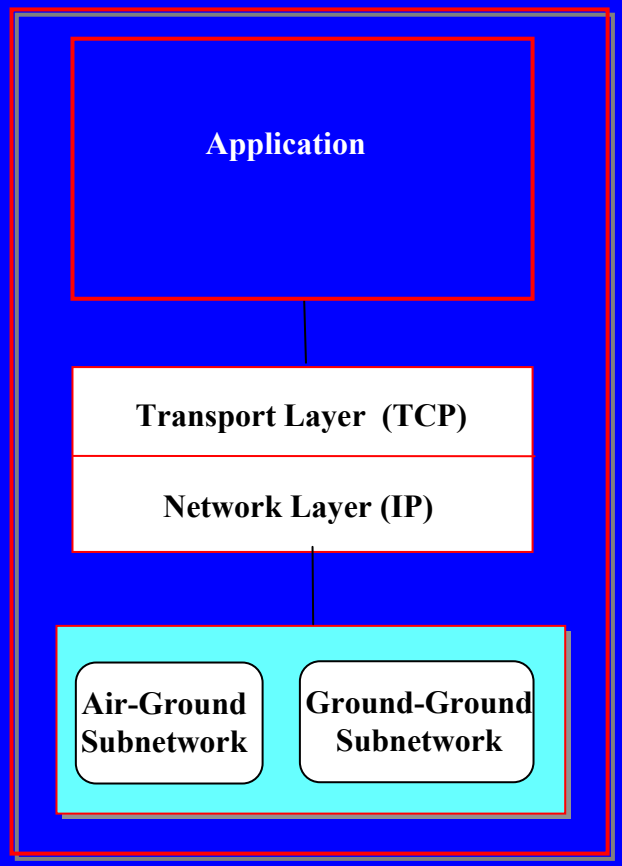
Fast Byte approach selected to obtain bit efficiency over the Air-Ground Link

ATN and TCP/IP Protocol Architecture

ATN Architecture



TCP/IP Architecture



With the Fast Byte enhancements, the two architectures appear similar in structure

ATN and TCP/IP Architecture Comparison

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Features and Capabilities	ATN	TCP/IPv6
Air-Ground Architecture	Functionally equivalent	Functionally equivalent
Ground-Ground Architecture	Full Stack and complex	Same as Air-Ground
Mobility Support	Limited Support	Full support-including mobility within mobility
Quality of Service (QoS)	Limited Services - priorities	Flows, TOS, DiffServ, RSVP, Real time protocols
Security	Security Label-Limited Capability-future based on PKI	IP Security (IPSec), more Capabilities, PKI available now
Multicasting	No support	Full support
Network Management	CMIP based -complex	SNMP based - simple
Cost	Few developer, expensive	Widely used, less expensive

Elements of the Study

- Identification of IP based services beyond the current ICAO ATN
  - File Transfer
  - Voice over IP
  - Web-Casting
  - Multicasting
  - Streaming Media
  - Quality of Service
  - Security
  - Network Management
- Analyzed in Operational Scenarios

Applications Integrated on IP-Technologies

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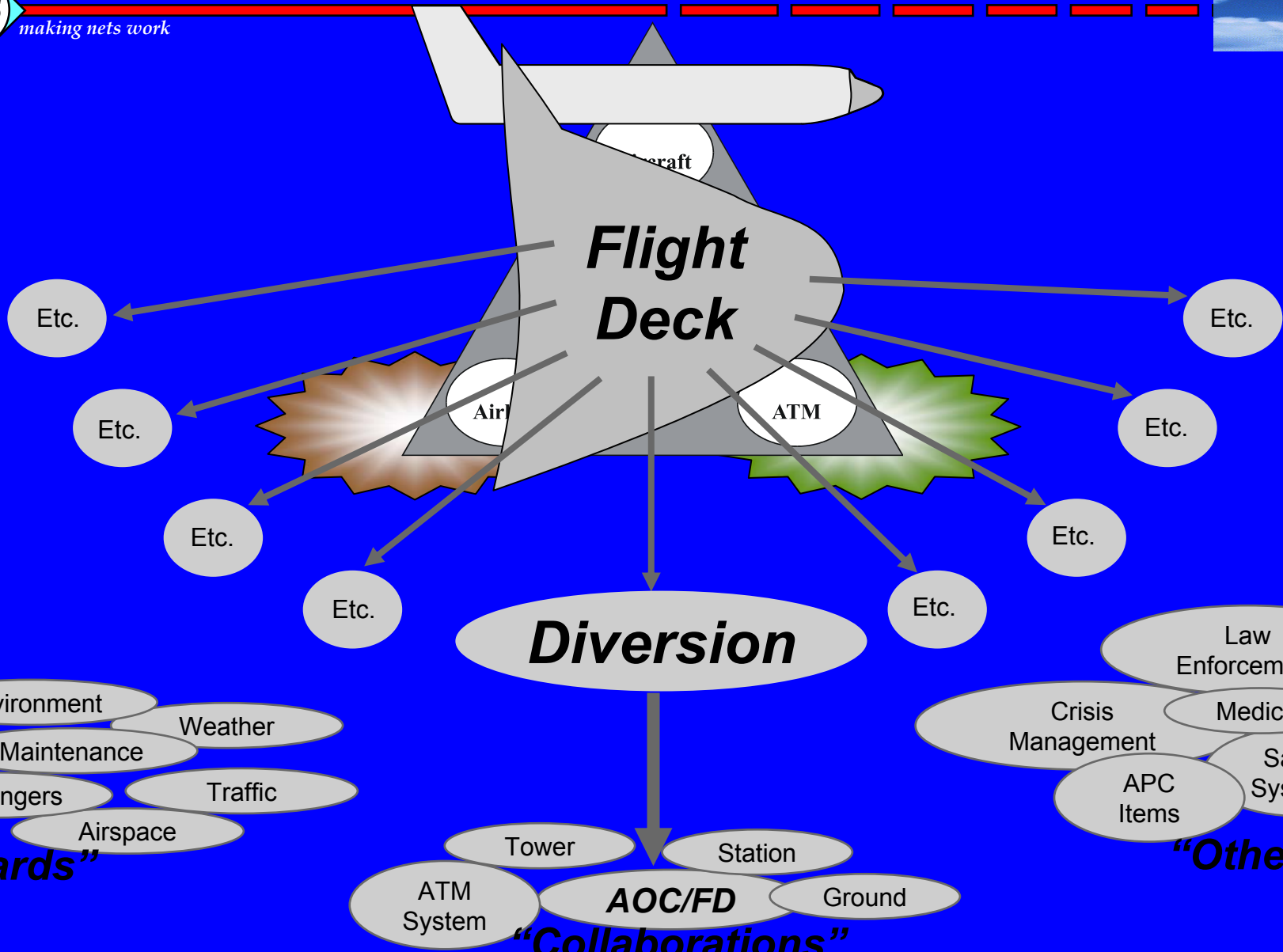

Application Benefits from Future Services

AVIATION APPLICATIONS THAT CAN BENEFIT	REPORT REFERENCE	FUTURE SERVICES							
		FTP	VoIP	Web-Casting	Multicasting	Streaming Media	Security	QoS	Network Mgmt
Weather Diversions	4.3.1	X	X	X	X	X		X	X
Passenger Accommodation Due to Schedule Disruption	4.3.2	X	X					X	X
Weather Graphics	2.4.1.2	X						X	X
Database Updates	2.4.1.2	X						X	X
Maintenance Procedures and Information	2.4.1.2, 4.3.4	X						X	X
Airport Information	2.4.1.2	X						X	X
Digital Voice as Replacement for Analog Voice	F.2.5		X					X	X
Digital Voice fed into Flight Dispatch Status Displays	F.2.5		X					X	X
ATC Digital Voice Copied to Flight Dispatchers	F.2.5, 4.3.5		X					X	X
Routine Transmissions	2.4.3.2			X				X	X
Pre-Flight Briefings	2.4.3.2, 4.3.6			X				X	X

Life Cycle Cost Results

Life Cycle Phase	TP4/CLNP	TCP/IPv6	Difference
Production	308,732,345	12,620,841	296,111,504
Operations & Support	79,815,000	1,110,500	78,704,500
Total	388,547,345	13,731,341	374,816,004

- **TP4/CLNP is 28 times more expensive to implement than TCP/IPv6.**

NASA GRC System Testbed Configuration

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Testbed Protocol Stack

- Controller Pilot Data Link Communications (CPDLC)
- Context Management (CM)
- Application Service Element (ASE)
- Dialogue Service
- Association Control Service Element
- FastByte COPP
- FastByte COSP
- Transport Switch
- COTP / TCP
- CLNP / IP
- MAC
- Physical

NASA DC-8 Experimental Aircraft

VHF Datalink

Transceivers

CMU (ATN compliant)

Display 'MCDU'

NASA Experimental CPDLC Ground System

'CMU'

LAN

Ground Controller Display

CMU (ATN compliant)

• 'MCDU'

• Telemetry
• Admin

NASA

Future Services Discussion Example

FMC

Other Apps
ADS User
CPDLC User
TCP IPv4

CMU

ADS Gateway
CPDLC Gateway
ASI
ASI
Other Apps
CM User
FIS User
ADS ASE
CPDLC ASE
CM ASE
FIS ASE
GW
TCP IPv4
ATN STACK

PN (profiled RFC 1122 LAN)
Air-Ground Subnetwork

Profiled Network (PN)

Router

Compliant Network (CN)

- Work under AEEC ATN WG 637 and ADN WG 664

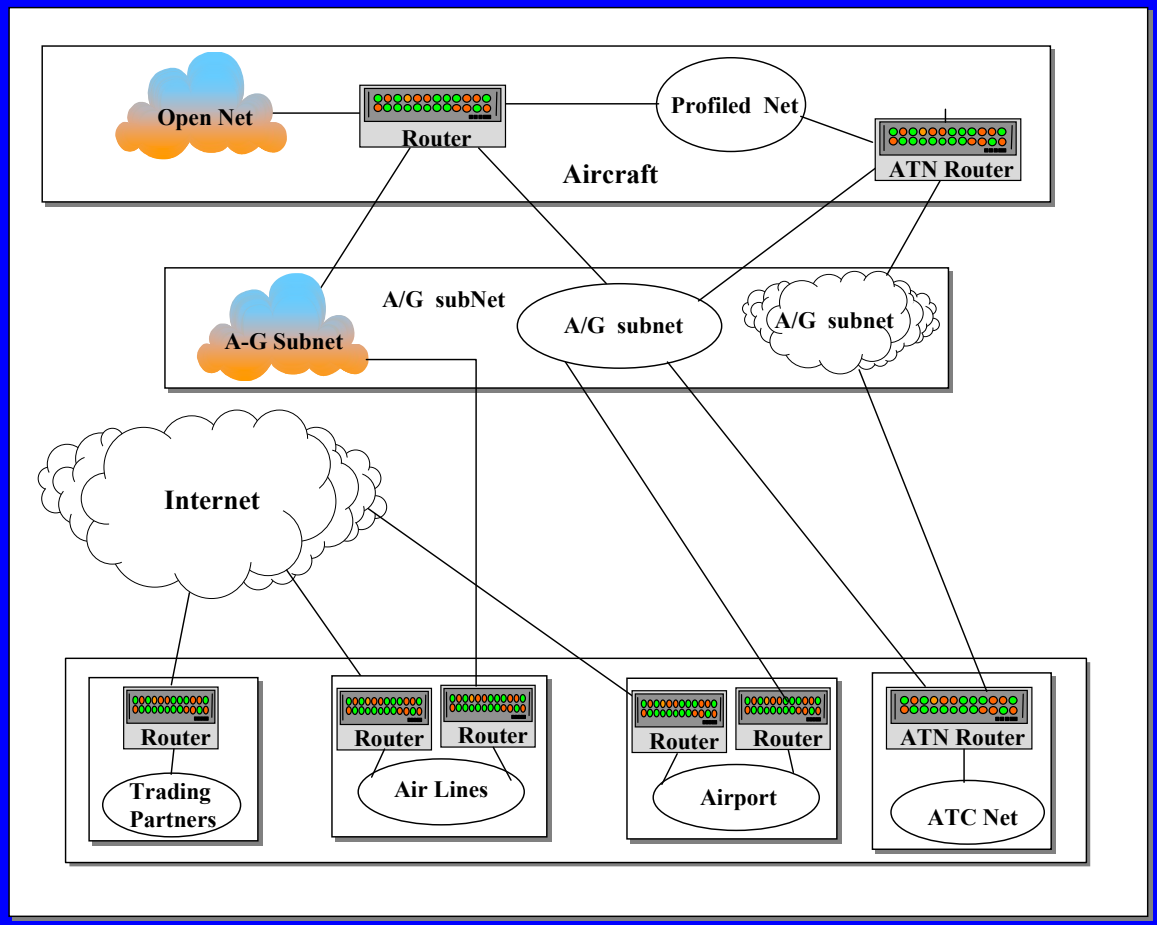
CABIN

CN (RFC 1122 Compliant LAN)
Broadband Satcom
Commercial SAT Provider

Future ATN/FIS Path

Future AOC Path

Network Architecture Framework



- Use of IP Internet
- Use of COTS products
- Multiple Service providers
- Minimize Gateways

IP-Based Application Migration

- Air Traffic Management (ATM)
  - Air Traffic Control (ATC)
  - Air Traffic Services (ATS)
  - Communication, Navigation, & Surveillance (CNS)
- Airline Operational Communications (AOC)
  - Flight Operations
  - Maintenance
  - Airport/Ramp Operations
- Airline Administrative Communications (AAC)
- Airline Passenger Communications (APC)
- Entertainment

Mobile IPv6 ?

Summary of "Gap" Issues Sorted by Relative Value

Ref No	Title	Relative Value	Relative Degree	Relative Cost
2	Commoditized Airspace	1a-High	1-High	1-High
4	Dynamic RF Assignment and Use New Process	1a-High	1-High	1-High
5	VHF RF Improved Data Link Concept	1a-High	1-High	1-High
11	Performance Test Measurement	1a-High	2-Middle	2-Middle
12	Satellite Based Communications	1a-High	1-High	2-Middle
16	Airborne Internet	1a-High	2-Middle	2-Middle
3	Frequency Use and Planning	1b-High	2-Middle	2-Middle
15	Use of COTS TCP/IP	1b-High	1-High	3-Low
19	VDL M3 Performance in Failure Modes	1b-High	1-High	3-Low
1	National Communications Traffic Loading Model	2a-Middle	2-Middle	1-Low
6	CPDLC-IA System Latency in Terminal Domain	2a-Middle	2-Middle	1-High
7	Impact of CPDLC-IA System Latency	2a-Middle	2-Middle	2-Middle
8	Multiple Radio Equipage	2a-Middle	2-Middle	2-Middle
9	Co-site and Antenna Isolation	2a-Middle	2-Middle	2-Middle
10	Transition Planning Central Focus	2b-Middle	2-Middle	2-Middle
13	Security/Vulnerability	2b-Middle	2-Middle	2-Middle
20	Human Factors Related Use of Communications Data Links	2b-Middle	2-Midd1e	2-Middle
17	Low Cost End Systems for GA	2c-Middle	2-Middle	2-Middle
14	Network Management	3a-Low	3-Low	3-Low
18	Use of COTS Wireless On-board (802.11 and Bluetooth)	3a-Low	3-Low	3-Low